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PICTURE MEMORY (PSEUDOMATCHING) IN THE RHESUS MONKEY

Lovelace Foundation for Medical Education
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Lovelace Foundation
P.O. Box 5890
Albuquerque, New Mexico 87115

15 October 1975

Topical Report



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| 20 ABSTRACT (Continue on reverse side if necessary and identify by block number) Pseudomatching, the selection of the correct comparison stimulus without dependence on presentation of a sample stimulus, was demonstrated in monkeys being trained on a shock-avoidance, matching-to-sample task. Pseudomatching occurred whenever the problem sets were not fully counterbalanced for key position and correct symbol and seemed to represent memorization of specific stimulus configurations. Some animals showed the capacity to memorize hundreds | | |

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20. ABSTRACT (Continued)

of different 4-choice problems as revealed by test trials on which the samples were omitted.

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PREFACE

This work was performed as a Nuclear Weapons Effects Subtask entitled "Neurophysiological Basis of Primate Performance Decrement," funded by the Defense Nuclear Agency under Contract Nos. DASA-01-70-C-0059 and DNA-001-74-C-0098. The present report points out potential pitfalls in matching-to-sample training regimens which may facilitate pseudo-matching, and indicates how same may be avoided.

The authors wish to express their gratitude to the following individuals who assisted in many phases of this research: R. D. Jeter, A. A. Almagro, Mary M. Sproul, and Dr. R. K. Jones.

This research was conducted according to the principles enunciated in the "Guide for Laboratory Animal Facilities and Care," prepared by the National Academy of Sciences, National Research Council.

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INTRODUCTION

In a matching-to-sample task one cannot always assume that above-chance matching accuracy is necessarily due to the control exerted by the sample stimulus. Farrer (1967) found while training three chimpanzees that, despite outward appearances, his subjects were not really matching-to-sample, but had instead memorized his 24 uncounterbalanced 4-choice problem sets and could select the correct match choice even when the sample was not presented. This occurred even with randomization of the trial sequence, so long as the total stimulus configuration remained intact. Fading out portions of the stimulus complex, or reversing the symbols to their mirror images resulted in performance decrement. Farrer also found that the "picture memory discrimination" could be acquired without experience with the sample.

D'Amato and O'Neill (1970) suggested that such "pseudomatching" could be prevented by use of a large number of different stimulus configurations and varying trial orders when restrictions on randomization were unavoidable due to limited programming capability. In addition, they proposed the use of pseudomatching probe trials, on which no sample stimuli are shown, as a test to disclose memorization tendencies.

The present paper describes our experience in producing and preventing pseudomatching in rhesus monkeys. The delayed matching-to-sample task employed was based on shock avoidance rather than food reinforcement, the latter having been used in the previous studies, because we were testing for radiation effects and could not use food reinforcement due to the disruptive gastrointestinal side effects of irradiation.

METHODS

More than 60 male, juvenile (2-3 kg) rhesus monkeys (Macaca mulatta) have been trained thus far under a variety of conditions on our delayed matching-to-sample task, the complete procedural details of which may be found in Bruner *et al.* (1975). Each monkey sat in a restraint chair facing a stimulus-response panel containing five, circular translucent keys, each 3.2 cm in diameter. The sample key was centered 6.5 cm above the row of four match keys, the latter being spaced 5.0 cm center-to-center. The stimuli were 55 multi-colored patterns (Figure 1) which were transilluminated onto the rear of the keys by a slide-coded projector. Two intensities of 60 Hz shock were administered via foot-restraint plates; a weak shock (6 - 13 mA, 0.50 sec) for

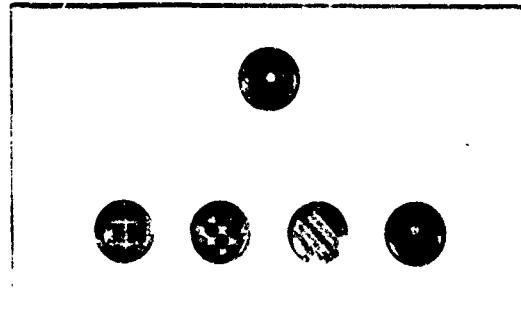
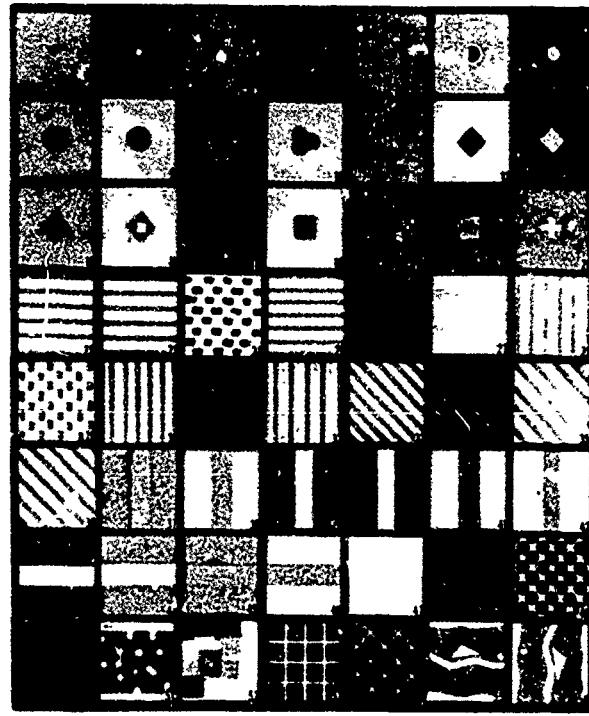


Figure 1. The 55 different stimuli employed. Each consisted of at least two colors, with a total of 10 different colors used. Pattern No. 55 is shown rotated 90 degrees as No. 56 as an example of how further stimulus variations were achieved to expand the array. At the bottom is shown the stimulus-response panel with a sample and four match choices illuminated. Color renditions of the stimuli are available from the first author on request.

incorrect choices and a strong shock (10-20 mA, 0.75 sec) for response omissions.

Training consisted of various shaping and correction procedures utilizing shock avoidance and successively approximating matching behavior. About three months of 200 trials per day (2-hr sessions) were required to bring the animal to the final matching stage. The matching trials were as follows: The sample key was illuminated with a pattern and the animal given 5 sec to press it in order to terminate the stimulus and avoid the strong shock. Failure to respond was shocked and after a 3-sec rest the sample was repeated. A sample response was followed immediately, or after a delay depending on the training stage, by illumination of the match keys, with one of the match keys displaying the same stimulus as had been shown on the sample key and with the other match key stimuli being distinctly different. A correct match choice avoided the weak shock, terminated the stimuli, and initiated a 10-sec intertrial interval. An incorrect match choice was punished with the weak shock and the trial terminated. A failure to respond was punished by the strong shock. In both latter cases a 5-sec intertrial interval followed.

A usual daily session consisted of up to five 40-trial blocks, each block separated by the few minutes

required for changing carousel slide trays. In the uncounterbalanced condition found conducive to picture memory, the same 40-trial block was repeated five times per day. Each matching problem appeared only once and in a constant stimulus configuration in each block, i.e., same correct key position and correct symbol. For example, the 4-choice problem illustrated at the bottom of Figure 1 would appear as shown with the right-hand key always correct, once within a given 40-trial block. This configuration would not appear in any of the other 39 problems of this block, although some of the symbols might be used again in different combinations.

Pseudomatching probes followed most training sessions. The pseudomatching test trials were identical to the matching trials except that the samples were omitted.

RESULTS AND DISCUSSION

Figure 2 presents percentage correct match choices over 200-trial blocks per day for one monkey. At the far left are shown two acquisition curves indicating memorization of 40, 2-choice problem sets which were presented in fixed sequence five times per day, with no counterbalancing of left-right position or correct symbol. (Only the central

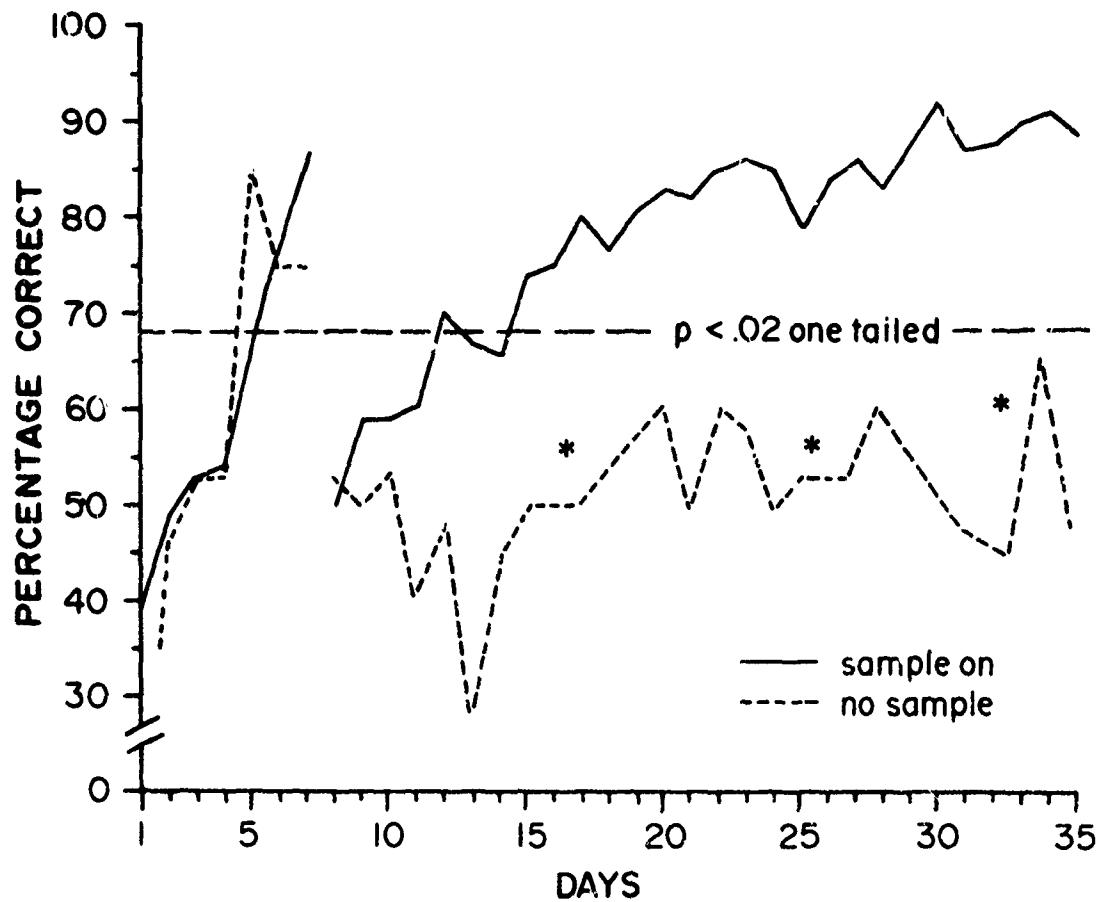


Figure 2. Percentage correct on a 2-choice task with and without sample presentation for a picture memory monkey. Left-hand curves: 40 uncounterbalanced problems in fixed sequence. Right-hand curves: 60 counterbalanced problems, randomized sequence. The daily, sample-on trial blocks contained 200 trials each. The daily, no-sample probes consisted of 40 trials each, with the subset of 40 varying daily for right-hand curves.

two of the four match keys were used here.) It is evident that this monkey did as well when the sample was absent as when it accompanied the comparison stimuli in this simultaneous matching task.

The right-hand curves in Figure 2 depict 2-choice simultaneous matching accuracy on 60 problems counterbalanced so that each problem appeared in each of the four possible ways as a result of alternation of key position and correct stimulus. Two hundred of the 240 problem sets possible were presented each day. Under this condition, the animal's matching and pseudomatching curves diverged over days as true matching accuracy approached 90% while pseudomatching remained in the 50's.

The three starred data points in Figure 2 indicate pseudomatching "accuracy" on the 40-problem series which was memorized initially and shown at the left of the figure. Subsequent to these 40 problems becoming a subset of the 240 counterbalanced recombinations, pseudomatching accuracy fell to about 60% correct from the earlier 80% indicating the animal's shift in strategy from memorization to matching. Still, many of the pseudomatching data points are greater than 50% more often than they are less. This probably stems from the fact that each 40-trial block was still being

administered in fixed sequence, so that memorization of some of the trials of each tray was still likely.

It should be pointed out that on the no-sample pseudomatching test trials a weak shock was administered for incorrect choices, as was done on the sample-on trials. The shock was found necessary to keep the animals working. At the same time this procedure would tend to facilitate memorization, since choosing the correct stimulus was reinforced by shock avoidance. Consequently, our test condition for disclosing picture memory also tended to foster it. But the shock administration was not an essential condition for picture memory, as we observed many animals to give evidence of prior memorization of the problem sets by the time we belatedly introduced pseudomatching probe trials.

Twenty-one monkeys were run in essentially the same manner as the monkey presented in Figure 2. Eleven showed picture memory similar to the animal illustrated, whereas the other 10 showed only true matching (i.e., no significant pseudomatching runs) yielding a near-equal division between subjects prone to memorize versus those that match-to-sample on the same 40-problem, uncounterbalanced set. Therefore the task, as presented, effectively divided the animals into two populations differing in their approach to solving the

task. The reasons underlying this split in preferred strategy remain obscure. We may speculate that we are witnessing individual differences in conceptual learning readiness, viewing matching-to-sample as a form of conceptual learning and picture memory as not. We cannot say that the memorization strategy was any less efficient in the present instance, however, since the numbers of trials to achieve significant performance accuracy were not different between the memorizers and matchers.

Other animals trained using fewer than 40 uncounterbalanced problem sets did not show the same strategy split, however. Five animals received 10, 2-choice uncounterbalanced problems repeated 10 times per daily session. The stimulus symbols were different for each problem. All five picture-memorized the array. Of five other monkeys receiving 20 different uncounterbalanced problems repeated six times per day, four showed picture memory. Although almost all showed picture memory under these two conditions involving fewer than 40 problems, their acquisition rates were no faster than the animals memorizing the 40-set array.

All of the monkeys, both memorizers and matchers, initially trained on a memorizable array, readily converted to, or continued to show, true matching behavior after

introduction of the large (60 problem) counterbalanced array, as did the subject in Figure 2. The former picture memory animals matched as accurately as those matching originally and there was no difference in overall training time to bring the animals to the final delayed matching-to-sample phase. Hence the initial memorization strategy, when allowed, seemed neither to hinder nor help the eventual acquisition of delayed matching behavior.

Partially counterbalanced problem arrays were also used for the training of some of the animals. Under this condition we found that the memorization-prone animals would eventually memorize the correct choice on some or all of those problem sets which were not presented in all possible counterbalanced ways. Whereas they would be forced to employ matching behavior on the fully counterbalanced problems, they would still tend to rely on picture memory on those trials where it was possible due to incomplete counterbalancing of key position and correct symbol. Thus, their pseudomatching probes would reveal chance performance on the counterbalanced problem sets and consistently correct choices on the uncounterbalanced configurations. It was not uncommon to see animals utilizing both matching and pseudomatching strategies under this condition. This was noticed

when the animal's sample-on performance accuracy was consistently higher than its no-sample accuracy, with the extent of the difference reflecting the degree to which matching behavior was employed to supplement picture memory. The experimenter must, therefore, examine individual trial outcomes on the daily no-sample probes to disclose any particular problem sets being correctly pseudomatched consistently. For example, it is possible for an animal to memorize only 14 2 choice-problems out of 40 to yield significantly beyond-chance accuracy ($p < .02$, one-tailed), assuming that the outcomes on the remaining 26 problems are determined by chance.*

* Likewise the "true matching" animal need "learn" only the equivalent of 14 of the 40 problems, the probability of which is enhanced by the subject's tendency to partition the controlling samples into nominal versus effective stimuli, as explained by D'Amato and O'Neill (1970). Percentage correct trials appear as a deceptively oversimplified measure of performance here when it is realized what a small proportion of the problems and the stimuli presented may actually be involved in determining the subject's choice accuracy.

The only way we have found to preclude the development of picture memory is through complete counterbalancing of key position and symbol correct plus sequence randomization. None of the 13 subjects receiving only fully counterbalanced and randomized problem sets from the outset of training has shown significant pseudomatching probes beyond the occasional, isolated runs expected by chance.

Trial order did not seem important for the development of picture memory by Farrer's chimpanzees (1967), nor did it in the present study. Five of the present monkeys, which received five different sequences of the same 40 uncounterbalanced problems daily, reached above-chance performance as quickly as did monkeys receiving a single sequence. Two of the five showed memorization whereas three were matching animals. The two picture memory animals demonstrated that they could perform at about the same high accuracy on the pseudomatching probes regardless of the trial sequence tested--backwards, forwards, completely reshuffled, etc. The same indifference to trial order has been demonstrated by numerous other pseudomatchers initially trained on only one fixed sequence. Consequently it appears that stimulus problem configuration can be the primary feature enabling picture memory. This was essentially Farrer's (1967) conclusion too.

Figure 3 shows the prodigious capacity of one monkey to memorize following extensive practice. Pseudomatching probes were not begun until after this animal had already received 61 days training on 200 different, uncounterbalanced 4-choice problems. After an additional 26 days, as shown in Figure 3, the animal achieved 98% correct without benefit of the sample's presence. On a reversed sequence probe of all 200 problems administered on the final day, he achieved 92% correct. Needless to say, whether or not a delay was interposed between the sample and match stimuli was irrelevant with respect to this animal's choice accuracy.

We would readily agree with D'Amato and O'Neill (1970) that, if complete counterbalancing and randomization cannot be arranged conveniently in a matching-to-sample paradigm, then pseudomatching probes should certainly be employed to determine whether the subject is memorizing or matching, as the monkey's capacity for memorization, when allowed the opportunity, is indeed remarkable.

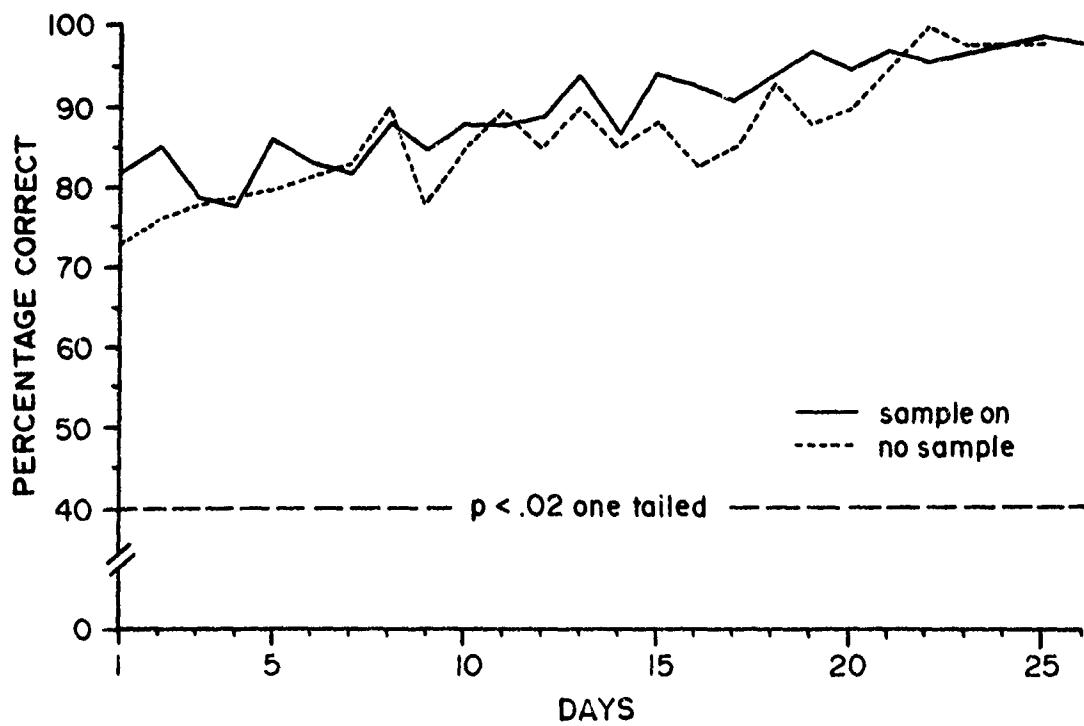


Figure 3. Percentage correct on a 4-choice task with and without the sample on the same 200 uncounterbalanced problems late in training for a picture memory monkey. The daily, sample-on trial blocks were 400 in length, divided into two sessions per day. The daily, no-sample probes consisted of 40 trials each, with the subset of 40 varying daily.

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